ORIGINAL ARTICLE

Mortality among Paris sewage workers

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Five additional tables are available on the *OEM* website (www.occenvmed.com/supplemental)

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Objectives: To describe the mortality of Paris sewage workers.
Methods: A cohort of all Paris sewage workers since 1970 was established and followed up in mortality until 1999. The causes of death were determined by matching with a national database. The mortality rates were compared to the rates of a local reference population.
Results: A large excess in mortality (standardised mortality ratio (SMR) = 1.25; 530 cases, 95% CI 1.15 to 1.36) and in particular mortality from cancer (SMR = 1.37, 235 cases) was detected which was particularly important in the subgroup of subjects who had left employment because they resigned or were laid off (SMR = 1.77; 50 cases). The excess mortality is to a large extent due to alcohol related diseases (SMR = 1.65, 122 cases) especially malignant (SMR = 1.85, 16 cases) and non-malignant (SMR = 1.68, 38 cases) liver diseases, lung cancer (SMR = 1.47, 68 cases), and infectious diseases (SMR = 1.86, 25 cases). The SMRs for some diseases (all cancers, cancers of the oesophagus and lung, all alcohol related diseases) seem to increase with duration of employment as a sewage worker. Other than lung cancer, smoking related diseases were not in excess.
Conclusion: The increased mortality by both malignant and non-malignant liver diseases is probably due to excessive alcohol consumption, but could be partially the result of occupational exposure to chemical and infectious agents and interactions of these factors. The excess lung cancer is unlikely to be due to an increased smoking prevalence.

Sewage workers are potentially exposed to a number of chemical and biological agents, and acute symptoms arising among sewage workers and other wastewater workers are well described.[1 2] However epidemiological literature concerning chronic effects are scarce and contradictory. To our knowledge, only four published studies have described the mortality or cancer incidence of subjects exposed to wastewater.[3–6] Depending on the studies, excesses in cancers of the larynx,[3] liver,[3] and stomach[3–5] have been observed. This paper reports on a mortality follow up of the population of Paris sewage workers.

POPULATION AND METHODS

Exposure

The Paris sewage system is a vast network of underground canals whose network duplicates nearly perfectly the street network. It drains the waste water towards the treatment plants. The sewage system consists of three typical environments:

- Small (primary) lines connect buildings to the sewage system. The diameters of these lines vary from 1.2 to 2.0 m. When these lines need to be cured, the sewage workers intervene directly with handheld tools.
- Secondary and main collectors (canals) regroup the output of the primary lines. These collectors are larger and small sidewalks allow the workers to walk along these canals. The clearing of these canals is done using wagons or boats allowing the regulation of the flow of the wastewater.
- More or less large sedimentation basins slow down the wastewater flow in order to get rid of the sediments which are extracted by aspiration from the streets.

The job of the sewage workers consists in the inspection of lines in order to detect any perturbation of the wastewater flow and possible defaults (for example, cracks, leaks) of the duct, the curing of the wastewater lines and the extraction of the sediments. In recent years the latter job has been subcontracted. Finally a number of maintenance tasks (for example, masonry, carpentry) are generally done by specialised personnel. In the past this also included more indirectly exposed personnel like shoemakers.

The sewage workers are exposed both to chemical and biological agents. A first source of exposure to chemical agents, in particular to sulphur compounds (hydrogen sulfide, mercaptans), carbon monoxide, methane, aldehydes, and organic acids, occurs through the decomposition of urine and faeces in either aerobic or anaerobic conditions. These chemicals are notably released in the air during the curing and extraction operations. A second possible source of chemical exposure is when industries dump their waste into the sewage system. In recent years this exposure diminished sharply because regulations on waste recycling became tighter and were enforced more strictly, and because the number of manufacturing plants within the city of Paris decreased regularly. However hundreds of chemical substances have been shown to exist in the wastewater.[7–9]

Biological exposure arises through inhalation of wastewater aerosols, skin contact with the wastewater, or ingestion, and includes potential exposure to Gram negative bacilii, endotoxins, faecal streptococci, and a range of viruses. A recent survey of the endotoxin exposure in Dutch wastewater treatment workers[2] however showed relatively low exposure levels (geometric mean 27 EU/m^3). Similar exposure levels were measured in Paris sewage workers (Duquenne P, Ambroise D, unpublished report).

Population and follow up

The population comprised all male Paris sewage workers having worked between 1 January 1970 and 31 December

1999. No selection on duration of employment was applied. The population was identified in the computerised register of all employees of the city of Paris. The extracted list was compared to the paper files of the personnel department responsible for the sewage workers. A final control of completeness was done by comparing the yearly numbers of sewage workers reported in historical reports of the corresponding personnel department.

The population was followed up for mortality between the 1 January 1970 and 31 December 1999. For each worker we gathered information on date and place of birth, end of employment, and cause of leaving employment, as well as full history as an employee of the city of Paris (similar to civil servant status) from the personnel files. This civil service-like status gives the sewage workers the right to retire with a full pension at age 50 under certain conditions. However no detailed job codes could be obtained. We assessed vital status by writing to the registry offices of the birthplaces and by searching a computerised database of all subjects who had died in France since 1978. Thus foreign born subjects were considered lost to follow up on the day of leaving employment. This procedure of identifying deceased subjects has been shown to be the most reliable in several cohort studies.[10–12] We obtained the cause of death by matching the file of deceased subjects with the national file of causes of death, which has existed since 1968. The causes of death are coded according to the 8th revision of the ICD until 1978 and according to the 9th until end of follow up.

Data analysis

We compared the mortality of the cohort with the death rates of the ''Département de Seine St Denis'' which is an administrative district within the Parisian region comprising more than a million inhabitants and is characterised by its large proportion of blue-collar workers. The Paris and regional mortality rates, due to the predominantly white-collar population, are much lower and are not an adequate reference.

Each worker contributed person-time to the follow up from the moment of his hire as a sewage worker or the 1 January 1970, whichever came later, to the time of death, loss to follow up, or 31 December 1999, whichever came first.

We obtained standardised mortality ratios (SMRs) by dividing observed numbers of deaths by causes and groups of causes by age period standardised expected numbers and computed exact 95% confidence intervals (95% CIs) with the usual Poisson assumption. In addition to the standard groupings of causes, we computed the rates for alcohol related diseases (cancers of the buccal cavity, pharynx, larynx, oesophagus, and the liver, non-malignant diseases of the liver and pancreatitis, and alcoholism (ICD291 and 303)). A second non-standard grouping of causes was the group of all infectious diseases, grouping all diseases of the first chapter of the ICD and all other infectious diseases (for example, pneumonia). AIDS was excluded from this group of causes, given its predominance as a cause of death among the infectious diseases since the late 1980s. SMRs were further obtained by cause of leaving employment and by duration of work as a sewage worker. Person-time at any time point was allocated to the category to which the death would have been allocated, had it occurred at this point in time.

The statistical analysis was performed using the STATA 8 software using the series of Stata's survival analysis routines (the ''st'' ado-files) (Stata, College Station, TX, USA).

RESULTS

The cohort comprised 1722 subjects, 408 of whom were still active and 1182 still alive at the end of follow up. While a majority of the subjects no longer at work (755) were retired or, to be more precise, were on a retirement pension, a significant part (269) of the cohort members left disabled—that is, for medical reasons and for other reasons (181). These individuals had usually been laid off or had resigned.

Follow up was nearly complete as only eight subjects were foreign born; for two subjects the birthplace was missing. The number of unknown causes for which no match could be found in the national database was small.

Overall, mortality was in excess (table 2; see also online table 1 at http://www.occenvmed.com/supplemental for more causes of death) which was mainly due to the large excess in cancer mortality. This excess was even larger when compared to national or regional rates (data not shown). The excess in cancer mortality is to a large extent due to cancers of the digestive tract, in particular cancer of the oesophagus and the liver. We note also the excesses of cancers of the pleura and the brain. Although the mortality from non-malignant respiratory diseases and cardiovascular diseases does not differ significantly from the expected, mortality from the diseases of the nervous system and from suicides are in significant excess. With respect to the risk factors potentially associated with the exposure, the significantly increased risks of all infectious diseases and non-malignant diseases of the digestive tract are of particular interest. Within the latter the increased risk of diseases of the liver not specifically related to alcohol is of particular interest, especially with regard to the high SMR for all diseases related to alcohol.

With respect to causes for leaving employment (table 3; see also online table 2 at http://www.occenvmed.com/supplemental), the group with the highest overall mortality is the group of subjects having left for other reasons—most of which had a very short duration of employment (data not shown). In this group, all causes—especially alcohol related diseases and infectious diseases—are in excess, which points towards a selected population for its bad life hygiene. As could be expected, the subjects who had left employment for medical reasons had a higher mortality than retired subjects. The mortality among active sewage workers was lower than in the other groups, with the exception of the significant excess of mortality from non-malignant diseases of the liver not specifically related to alcohol.

When including the subjects who had left for ''other reasons'' the mortality of the short term employees (less than 10 years) is high for many causes (data not shown but

Table 1 Cohort characteristics

	n	%
Subjects by vital status		
Alive at end of follow up	1182	69%
Deceased with known cause	515	30%
Deceased with unknown cause	15	1%
Lost to follow up	10	1%
Subjects by cause of leaving employment		
Active at end of follow up	408	24%
Died while active	109	6%
Retired	755	44%
Left for medical reasons	269	16%
Left for other reasons	181	11%
Total number of subjects	1722	100%
Mean duration of follow up in years	21.9	
Number of person-years by age		
<40 years	9875	26%
40–49 years	10519	28%
50–59 years	9573	25%
60–69 years	5868	16%
>70 years	1954	5%
Total number of person-years	37788	100%

Table 2 Mortality from main causes of death

Cause of death (codes from ICD 9)	Observed	Expected	SMR	95% CI
All causes	530	423.65	1.25	1.15–1.36
All cancers (1–208.9)	235	171.07	1.37	1.20–1.56
Upper digestive tract (140–151)	52	33.70	1.54	1.15–2.02
Lip, oral cavity, pharynx (140–149)	25	15.75	1.59	1.03–2.34
Oesophagus (150)	22	11.15	1.97	1.24–2.99
Stomach (151)	5	6.80	0.74	0.24–1.72
Other digestive (152–159)	42	29.73	1.41	1.02–1.91
Liver (155)	16	8.65	1.85	1.06–3.00
Nasal cavities and sinuses (160)	8	4.97	1.61	0.69–3.17
Larynx (161)	10	9.28	1.08	0.52–1.98
Lung (162)	68	46.27	1.47	1.14–1.86
Pleura (163)	3	1.68	1.79	0.36–5.22
Bladder (188)	4	5.74	0.70	0.19–1.78
Brain (191)	5	2.58	1.94	0.63–4.52
All diseases of the nervous system (290–315)	15	6.58	2.28	1.27–3.76
Alcohol dependence syndrome (303)	8	4.3	1.86	0.80–3.67
All cardiovascular diseases (390–459)	105	97.25	1.08	0.88–1.31
Ischaemic heart diseases (410–414)	37	40.68	0.91	0.64–1.25
Non-malignant respiratory diseases (460–519)	20	20.51	0.98	0.60–1.51
COPD (491, 496)	7	6.69	1.05	0.42–2.16
Infectious respiratory diseases (460–474, 472–473)	10	6.45	1.55	0.74–2.85
Non-malignant diseases of the digestive tract (520–579)	48	34.01	1.41	1.04–1.87
Chronic liver diseases explicitly related to alcohol (571.0–571.3)	17	12.60	1.35	0.79–2.16
Other chronic non-malignant diseases of the liver (571.4–571.9)	21	10.04	2.03	1.25–3.10
All violent causes (E800–E999)	34	26.52	1.28	0.89–1.79
Suicides (E950–E959)	16	5.52	2.90	1.66–4.71
All infectious diseases (see text)	25	13.41	1.86	1.21–2.75
All alcohol related diseases (see text)	122	73.95	1.65	1.37–1.97

COPD, chronic obstructive pulmonary disease.

Table 3 Standardised mortality ratios (number of deaths) from selected causes according to causes for leaving employment

Cause of death	Active (517) (95% CI)	Retired (755) (95% CI)	Medical reasons (269) (95% CI)	Other reasons (181) (95% CI)
All causes	1.12 (107) (0.92–1.35)	1.19 (265) (1.05–1.35)	1.39 (108) (1.14–1.68)	1.77 (50) (1.32–2.34)
All cancers	1.15 (35) (0.80–1.59)	1.40 (133) (1.18–1.66)	1.35 (46) (0.99–1.80)	1.81 (21) (1.12–2.77)
Oesophagus	1.15 (3) (0.24–3.37)	1.59 (9) (0.73–3.02)	2.83 (6) (1.03–6.16)	5.10 (4) (1.39–13.1)
Liver	2.25 (2) (0.27–8.11)	2.29 (12) (1.18–4.00)	1.05 (2) (0.13–3.78)	0
Lung	0.68 (5) (0.22–1.59)	1.53 (40) (1.09–2.08)	1.57 (15) (0.88–2.60)	2.47 (8) (1.06–4.87)
All cardiovascular diseases	0.95 (15) (0.53–1.57)	0.93 (53) (0.70–1.22)	1.49 (28) (0.99–2.15)	1.55 (9) (0.71–2.95)
Ischaemic heart diseases	0.99 (7) (0.40–2.05)	0.69 (16) (0.39–1.12)	1.14 (9) (0.52–2.16)	2.02 (5) (0.66–4.72)
Chronic liver diseases explicitly related to alcohol	1.03 (4) (0.28–2.64)	1.60 (9) (0.73–3.03)	1.39 (3) (0.29–4.05)	1.09 (1) (0.03–6.10)
Other chronic non-malignant diseases of the liver	2.69 (9) (1.23–5.10)	0.65 (3) (0.13–1.90)	3.45 (6) (1.26–7.51)	4.48 (3) (0.93–13.2)
All infectious diseases	1.32 (4) (0.36–3.38)	1.81 (13) (0.96–3.10)	1.26 (3) (0.26–3.69)	6.13 (5) (1.99–14.3)
Alcohol related diseases	1.39 (28) (0.92–2.00)	1.62 (57) (1.23–2.10)	1.79 (24) (1.15–2.67)	2.50 (13) (1.33–4.28)

Table 4 Standardised mortality ratios (number of deaths) from selected causes according to duration of employment after exclusion of subjects having left for other reasons

	<10 years	10–19 years	20 years +
All causes	1.16 (27) (0.77–1.69)	1.14 (186) (0.99–1.32)	1.27 (267) (1.13–1.44)
All cancers	0.88 (5) (0.29–2.06)	1.27 (81) (1.01–1.58)	1.42 (128) (1.19–1.69)
Oesophagus	0	0.70 (3) (0.14–2.05)	2.63 (15) (1.47–4.34)
Liver	0	2.70 (8) (1.17–5.33)	1.65 (8) (0.71–3.24)
Lung	0.76 (1) (0.02–4.23)	1.13 (19) (0.68–1.77)	1.60 (40) (1.15–2.18)
All cardiovascular diseases	1.31 (4) (0.36–3.36)	0.91 (34) (0.63–1.27)	1.14 (58) (0.86–1.47)
Ischaemic heart diseases	1.61 (2) (0.19–5.81)	0.70 (11) (0.35–1.26)	0.89 (19) (0.54–1.39)
Chronic liver diseases explicitly related to alcohol	0	0.99 (5) (0.32–2.30)	1.86 (11) (0.93–3.32)
Other chronic non-malignant diseases of the liver	1.75 (1) (0.04–9.75)	2.29 (10) (1.10–4.21)	1.47 (7) (0.59–3.03)
All infectious diseases	0	1.52 (8) (0.65–2.99)	1.83 (12) (0.94–3.19)
Alcohol related diseases	1.18 (4) (0.32–3.01)	1.49 (43) (1.06–1.98)	1.72 (62) (1.32–2.20)

available in online tables 3 and 4 at http://www.occenvmed.com/supplemental). When excluding these subjects (table 4; see also online table 5 at http://www.occenvmed.com/supplemental) the mortality from cancer increases with duration of employment as a sewage worker, although non-significantly. This increase can also be seen for cancer of the oesophagus and lung cancer, while mortality from liver cancer is highest in the group having worked for 10–20 years. No clear pattern can be distinguished in the analysis by time since first employment as a sewage worker (data available online).

DISCUSSION

The main findings of this study are the overall excess mortality compared with the expected, the excess mortality for cancer and, within those, the excess for lung cancer and liver cancer. Among the other causes of death in noticeable excess are the non-malignant liver diseases not specifically related to alcohol and the excess from infectious diseases.

Our results are stated as comparisons with reference rates with a nearby geographical area whose socioeconomic structure seemed more adequate than either the national or the Parisian population—for example, the expected number of pleural cancers were 1.00 with national rates compared to the 1.68 with the rates we used. Had we used national rates, most of the SMRs would have been higher especially with respect to cancer. However it is impossible to assess the bias involved in this comparison. Another methodological weakness of this study is the absence of any precise job codes. Given that the identified population exceeded the numbers of sewage workers mentioned in historical documents, it is probable that a number of subjects whose actual job was not in the sewers but who were administratively attached to the sewage workers, were included in this population. A consequence is a possible dilution of a possible occupational risk. However the excess number of subjects was less than 10% of the population.

One of the main features in the mortality of this population is the increased mortality from alcohol related diseases. Interviews with managers and occupational physicians confirmed that excessive alcohol consumption was, or at least had been, a major hazard in this population. Less than optimal personal hygiene is also documented by the excess mortality from infectious diseases. However it is highly unlikely that this excess in infectious diseases is due to occupational factors as most of the excess arose after the subject left employment. A particularly fragile group is the group of subjects who left for other reasons. Given the social advantages (in particular early retirement) attached to the job as a Paris sewage worker, this group probably consists of socially unstable subjects.

The excess of chronic diseases of the liver (both malignant and non-malignant) may however not only be attributable to the excessive alcohol consumption. Thus the excess of liver diseases explicitly related to alcohol is of a lesser excess than other liver diseases, which could point towards an occupational origin. Of course, the fact that alcohol is not mentioned in the cause does not mean that it is absent, and some misclassification is likely; however there is no reason why this misclassification should be larger among the death codes of sewage workers than in the general population. Among the possible causes for chronic non-malignant liver diseases are infections via the hepatitis viruses. The hepatitis A virus seroprevalence in Paris sewage workers was found to increase with age, reaching 80% for workers older than 40, in a recent cross sectional study.[13] However no difference in seroprevalence was found in a group of workers from a the largest wastewater treatment plant nor in a group of non-exposed controls. This agrees with a recent review[14] which did not confirm an increased risk of hepatitis A prevalence in workers exposed to sewage. On the other hand, among the detailed causes only two were coded ICD9-571.4—that is, chronic hepatitis, with 10 coded ICD9-571.5 (cirrhosis of liver, not otherwise specified) and nine coded ICD9-571.9 (chronic liver disease, not otherwise specified). On the other hand hepatitis A, contrary to hepatitis B and C, is not known to be a risk factor for cirrhosis. In this context the recent study of Arvanitidou *et al* describing a hepatitis B seroprevalence related to occupational exposure to sewage is of particular interest.[15] However no such information is available for Paris sewage workers.

> **Main messages**
>
> - The mortality of the Paris sewage workers is increased mainly as a result of alcohol related diseases.
> - Significant mortality excesses from malignant and non-malignant liver disease as well as from lung cancer may be partially caused by occupational exposure.

The statistically significant excess of mortality from liver cancer we observed is noteworthy not only in the context of an increased mortality from cirrhosis, as a similar excess was observed both among Buffalo sewage workers[3] (3 cases *v* 0.6 expected) and among Danish wastewater workers[6] (4 cases *v* 0.8 expected). Note that we did not include biliary tract cancers (one further case) as these are coded 156 in ICD9. In both these cohorts no excess mortality exists with respect to other alcohol related diseases. Hansen *et al* discuss the possibility of an aflatoxin B exposure, a mycotoxin produced by certain *Aspergillus* species which is believed to be responsible together with hepatitis and cirrhosis for most liver cancer especially in poor countries.[6] A few measurements with a bioaerosol impactor (unpublished internal report) carried out in the sewage showed the presence of *Aspergillus* species in the ambient air. Thus it is not impossible that the sewage workers were exposed to airborne aflatoxin B. However, so far, the carcinogenic potential for the liver from aflatoxin exposure has only been shown with the direct ingestion of contaminated crops. Nothing is known concerning risk of liver cancer with respect to airborne exposure. Hansen *et al* also mention the possibility of exposure to halogenated solvents, which have been shown to exist in the Copenhagen sewers.[6] Although no comparable data exist for the Paris sewers, we have little doubt that the exposure is similar. However the first aetiology of these excesses in liver cancer mortality that one thinks of is alcoholic cirrhosis and this cause is mentioned explicitly as an associated cause of death for five cases, two of which had hepatitis as a secondary associate cause (one hepatitis B ICD9 070.3, one unspecified, ICD9 070.5), moreover two other cases had chronic liver diseases as associate causes (one non-specific cirrhosis ICD9 571.5 and one non-classified chronic liver disease ICD9-571.8). Given the preceding discussion, the most likely cause for the excess in liver cancer mortality is a combination of excessive alcohol consumption and occupational factors among which occupation induced infectious diseases are the most likely factor. Even before the results of the present study were known, the medical unit of the city of Paris responsible for the medical follow up of the sewage workers started an ongoing action of alcoholism prevention, and in recent years the vaccination against both hepatitis A and B became compulsory for all sewage workers as well as strict hygiene requirements aimed at reducing the exposure to infectious agents. It can therefore be expected that the increased mortality from liver diseases will be reduced in the future.

A second cancer site in significant excess is the lung. This is to be interpreted bearing in mind that the observed mortality from most of the other causes whose main aetiology is smoking is close to the expected mortality. Thus the SMR for bladder cancer is 0.70 (four cases), cancer of the larynx 1.08 (10 cases), chronic obstructive pulmonary disease 1.05 (seven cases), and ischaemic heart disease 0.91 (37 cases) which does not suggest a high smoking prevalence. On the other hand a recent survey carried out in 2002 indicated that the present smoking prevalence is high, with 71% smokers or ex-smokers. The excess from pleural cancers (SMR = 1.78), although based only on three cases, is noteworthy too especially because no asbestos has been used by the sewage workers and because the mortality rates in the reference population are among the highest in France. This indirectly suggests that toxic industrial substances have probably been dumped in sewers in the past, which could explain at least partially the excess in lung cancer. The fact that the lung cancer SMRs increase with duration of employment as a sewage worker (SMR = 1.60, 40 cases for subjects with more than 20 years employment) is a further indication as to a possible occupational risk.

Finally we comment on two other cancer sites. Mortality from cancer of the nasal cavities and sinuses are in non-significant excess, although the known occupational aetiologies (wood dust and nickel compounds) seem unlikely in the present context. It must be noted that a similar excess was found by Friis *et al*.[4] No excess of stomach cancer (SMR = 0.74, five cases) was found contrary to the wastewater workers in Buffalo,[3] Sweden,[4] and Italy.[5]

CONCLUSION

The increased mortality by both malignant and non-malignant liver disease is probably the result of excessive alcohol consumption but could be partially caused by occupational exposure to chemical and infectious agents and interactions of these factors. The excess lung cancer is unlikely to be caused by an increased smoking prevalence.

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